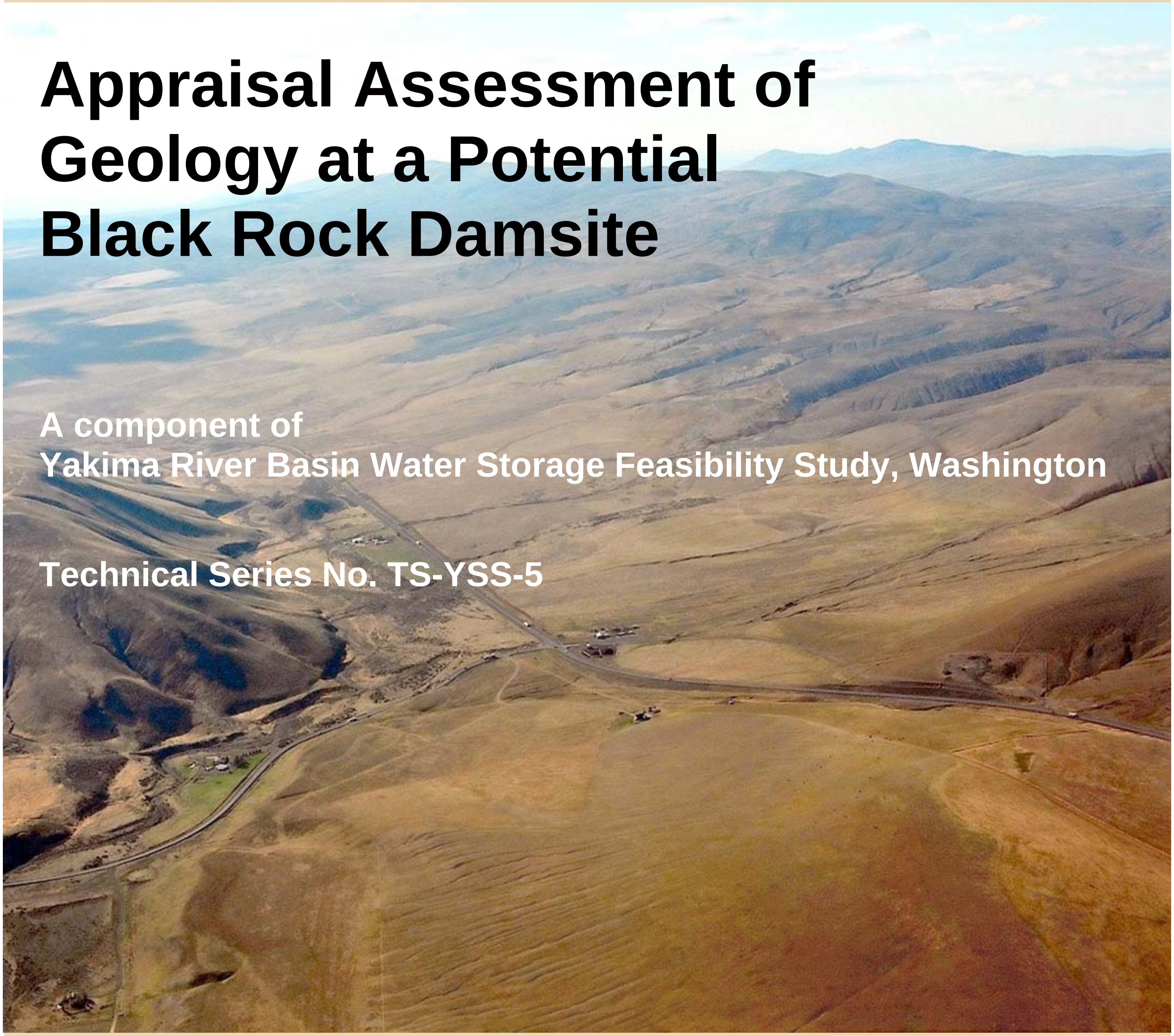
RECLAMATION

Managing Water in the West

Appraisal Assessment of Geology at a Potential Black Rock Damsite

A component of
Yakima River Basin Water Storage Feasibility Study, Washington

Technical Series No. TS-YSS-5



Black Rock Valley

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region

December 2004

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U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Regional Resource & Technical Services
Geology, Exploration & Instrumentation Group
Boise, Idaho

December 2004

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

Bureau of Reclamation
Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Preface

Congress directed the Secretary of the Interior, acting through the Bureau of Reclamation (Reclamation), to conduct a feasibility study of options for additional water storage for the Yakima River basin. Section 214 of the Act of February 20, 2003, (Public Law 108-7) contains this authorization and includes the provision "… with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock Reservoir and the benefit of additional storage to endangered and threatened fish, irrigated agriculture, and municipal water supply."

Reclamation initiated the *Yakima River Basin Water Storage Feasibility Study* (Storage Study) in May 2003. As guided by the authorization, the purpose of the Storage Study is to identify and examine the viability and acceptability of alternate projects by: (1) diversion of Columbia River water to the potential Black Rock reservoir for further water transfer to irrigation entities in the lower Yakima River basin as an exchange supply, thereby reducing irrigation demand on Yakima River water and improving Yakima Project stored water supplies, and (2) creation of additional storage within the Yakima River basin. In considering the benefits to be achieved, study objectives will be to modify Yakima Project flow management operations to most closely mimic the historic flow regime of a Yakima River system for fisheries, provide a more reliable supply for existing proratable water users, and provide additional supplies for future municipal demands.

State support for the Storage Study was provided in the 2003 Legislative session. The capital budget included a $4 million appropriation for the Department of Ecology (Ecology) with the provision the funds "… are provided solely for expenditure under a contract between the department of ecology and the United States bureau of reclamation for the development of plans, engineering, and financing reports and other preconstruction activities associated with the development of water storage projects in the Yakima river basin, consistent with the Yakima river basin water enhancement project, P.L. 103-434. The initial water storage feasibility study shall be for the Black Rock reservoir project."

Reclamation's Upper Columbia Area Office in Yakima, Washington, is managing and directing the Storage Study. Pursuant to the legislative directives, Reclamation has placed initial emphasis on Black Rock alternative study activities. These study activities are collectively referred to as the Black Rock Alternative Assessment (Assessment).

The Assessment has three primary objectives. First, it provides the emphasis directed by Federal and State legislation. Second, it builds upon prior work and studies to provide more information on the configuration and field construction cost of the primary components of a Black Rock alternative. It examines legal and institutional considerations of water supply and use, and identifies areas where further study is needed. Third, it is a step forward in identifying the viability of a Black Rock alternative.

This technical document, prepared by Reclamation's Pacific Northwest Regional Geology, Exploration & Instrumentation Group, Boise, Idaho, is one of a series of documents prepared under the Storage Study. This particular document is a component of the Assessment reporting on preliminary geologic investigations conducted in 2003 and 2004 at the alternate Black Rock damsite. Information and findings of this technical document are included in the Assessment Summary Report.

Further Consultations

The information available at this time is necessarily preliminary, has been developed only to an appraisal level of detail, and is therefore subject to change if this alternative is investigated further in the course of the Yakima River Basin Storage Feasibility Study (Storage Study). Finally, economic, financial, environmental, cultural, and social evaluations of the Black Rock alternative have not yet been conducted.

The policy of the Bureau of Reclamation (Reclamation) requires non-Federal parties to share the costs of financing feasibility studies and the eventual construction of Federal reclamation projects. In light of this policy, the preliminary cost estimates presented in the Assessment Summary Report, and current Federal budgetary constraints, Reclamation is not reaching a decision at this time as to whether the Black Rock alternative will be carried forward into the next phase of the Storage Study or dropped from further consideration. Rather, Reclamation will consult with the State of Washington (which is cost sharing in the Storage Study), the Yakama Nation, the potential water exchange participants, project proponents, and other interested parties before making a decision in this regard. It is anticipated that a decision will be reached by the fall of 2005.

If the Congress provides further funding for the Storage Study, all technically viable alternatives would be compared and an alternative(s) selected for further analyses in the feasibility phase. (Whether the Columbia River-Yakima River water exchange concept in the form of the Black Rock alternative is included will depend upon whether Reclamation, after these additional consultations, decides to carry that alternative forward into the plan formulation phase of the Storage Study.) The selected alternative(s) would then be subject to detailed evaluation in the feasibility phase in terms of engineering, economic, and environmental considerations, and cultural and social acceptability. This feasibility phase would be the last phase of the Storage Study. Preparation of the Feasibility Report/Environmental Impact Statement would be a part of this final phase.

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SUMMARY AND CONCLUSIONS

The original Black Rock Damsite was investigated by a private engineering consulting firm in 2002 and 2003. That study suggested that a more suitable damsite may lie west of the original study area. Based on the available understanding and mapping at the time, the location further west was thought to be less complicated due primarily to the presence of a potential north-south fault thought to place the bedrock nearer the ground surface.

Bureau of Reclamation forces performed investigations at the alternate Black Rock Damsite in 2003 and 2004. These investigations included drilling holes to determine the depth to bedrock along the alternate alignment, drilling a single core hole to obtain samples of the deep foundation to determine engineering characteristics and provide a pilot hole for a ground-water test hole, and performing a reconnaissance survey for borrow materials.

Five bedrock confirmation holes were drilled at the alternate site. The holes were drilled on the lower abutments and in the channel area. The information from these holes showed that the depth to bedrock (overburden thickness) is greater at the alternate alignment than at the original damsite. Using this data, the engineer's estimate for the total embankment quantities showed that the alternate alignment would require approximately 10,000,000 cubic yards (yd^3) more than the original site. Based on these estimates it was determined the original site is best suited for the structure.

The upper foundation at the damsites is composed of Quaternary loessial and alluvial deposits underlain by sediments of the Tertiary Ringold Formation. The deep foundation bedrock is composed of volcanic rocks of the Saddle Mountain Basalt Formation of the Columbia River Basalt Group. The geologic and engineering properties of the shallow and deep foundation materials are similar at both damsites.

Three ancient landslides identified on the Horsethief Mountain ridge are located near the south (right) abutment at the original damsite; two landslides are upstream from the damsite, one of which is on the north slope and the other is in the reservoir basin; the third is downstream from the damsite.

Construction materials for the dam and associated structures can be obtained from both developed and undeveloped land within approximately 35 miles of the site. Geologically, the sources consist of recent Yakima and Columbia River alluvium, post-Yakima Fold Belt alluvium, and Columbia River basalt.

Nineteen potential borrow material sites were identified during the reconnaissance survey. The main material types for the dam include impervious fill, rockfill, processed material for filter and drain elements, and concrete aggregate and sand.

It is common practice to obtain material from the reservoir basin during construction of large embankment dams. The Black Rock Valley and possibly Dry Creek Valley, south of the damsite, are potential sources for zoned earthfill for the embankment. Mining in the Black Rock Valley would have to be performed in a manner that would not compromise the water-holding ability of the reservoir basin or increase seepage in the vicinity of the dam. The likely area would be at the upper end of the valley, furthest from the damsite where reservoir depth is minimal.

In order to meet gradation requirements for filter, drain, and concrete aggregate, washing and screening of raw material will be necessary. The nearest sources of relatively clean material include Columbia River or Yakima River alluvial deposits, where well-sorted sand and gravel with minimal fines and wash water for processing are readily available.

INTRODUCTION

Section 214 of the Act of February 20, 2003, Public Law 108-7, authorized the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to conduct a feasibility study of options for additional water storage in the Yakima River Basin with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock Reservoir.

The Yakima River Basin Water Enhancement Project feasibility study conducted in the 1980's included possible storage by enlarging an existing reservoir or constructing an offstream reservoir within the Yakima River Basin. More recently Washington Infrastructures Services, Inc. (WIS) investigated the Black Rock Damsite in December 2002 and prepared a final report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation*, dated January 2003 (Washington Infrastructure Services, Inc., 2003). WIS completed the study for Benton County, Washington, which addressed pumping water from the Columbia River for storage in a proposed Black Rock Reservoir. This water would then be made available for irrigation, instream flow enhancement, and municipal purposes in the Yakima River Basin. Water would be delivered to the Roza and/or the Sunnyside Canals in exchange for part or all of their Yakima River Basin water supply. The exchanged water could then be used for instream flow enhancement and/or for irrigation in dry years.

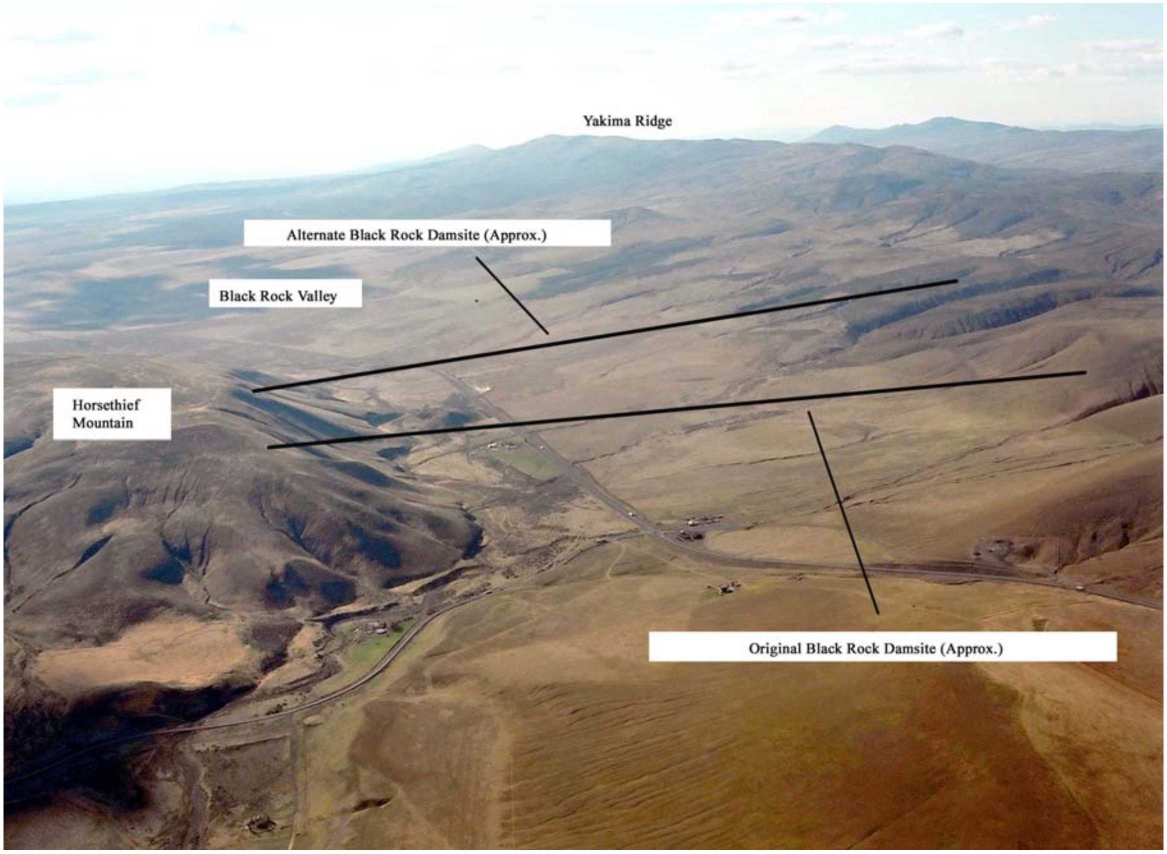
Purpose

WIS completed field investigations of the original dam site in December 2002. The WIS report states that a north-south trending discontinuity (fault) may exist across the valley just west of the original alignment. The report suggested investigating an alternate alignment located about one-half mile west of the original site (refer to Photograph 1). The investigations were intended to determine if the offset along the postulated fault places foundation bedrock nearer the ground surface, which would reduce overburden thickness and project costs.

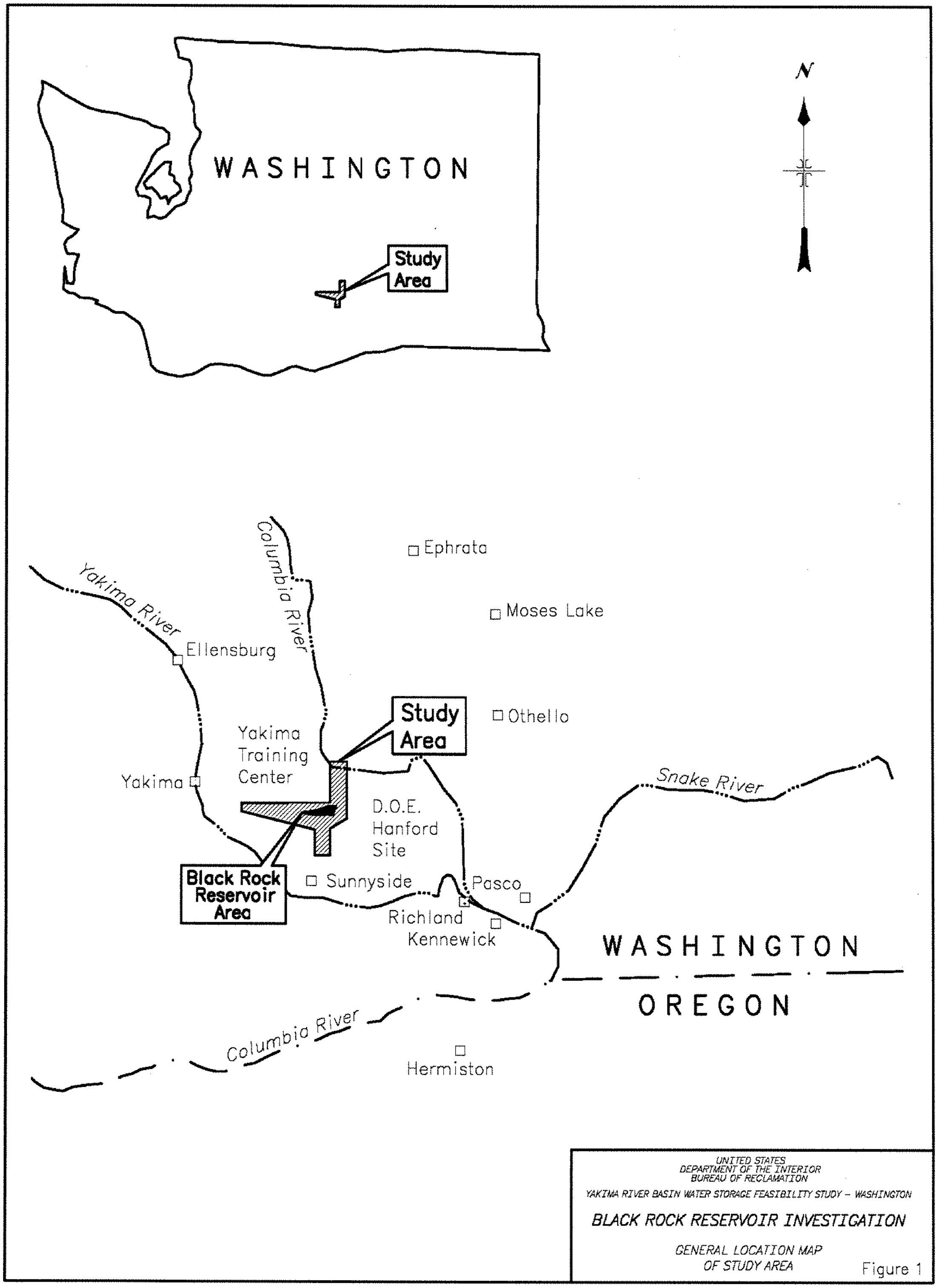
This report summarizes the findings of the exploratory drilling program conducted at the alternate Black Rock Damsite. The data collected were used to assess the suitability of the foundation at the alternate site for the proposed embankment. The field program involved drilling along the alternate alignment to confirm the depth to bedrock and determine if a north-south structural discontinuity exists between the two dam sites. In addition to the drilling program, a reconnaissance-level borrow material investigation was conducted.

Location

The Black Rock Damsites are located in the Black Rock Valley about 24 miles east of Yakima, Washington via State Highway 24 through the Moxee Valley (refer to Figure 1). The original Black Rock Damsite is located in Section 12 and the N1/2 of Section 13, T.12 N., R. 23 E. The alternate Black Rock Damsite is located in the N1/2 of Section 14, Section 11, and the S1/2 of Section 2, T.12 N., R. 23 E.



Photograph 1. View looking west at Black Rock Valley and the approximate location of the damsites. Horsethief Mountain forms the south (right) abutment and the Yakima ridge the north (left) abutment. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington - Bureau of Reclamation photograph taken by D.M. Walsh, June 17, 2003.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY – WASHINGTON

BLACK ROCK RESERVOIR INVESTIGATION

GENERAL LOCATION MAP
OF STUDY AREA

Figure 1

Previous Investigations

WIS investigated the Black Rock Damsite in December 2002 and prepared a final report in 2003. This investigation was funded by Benton County through a grant from the State of Washington. The investigation program consisted of conducting geologic mapping and completing five test borings, nine test pits, water pressure testing, and a geophysical refraction survey. Two important conclusions were drawn from this investigation. First, the depth to bedrock in the main section of the damsite was considerably deeper than the 25 feet initially estimated, reaching depths as great as 216 feet in the maximum section. Also, the basaltic lava flows that form the bedrock at the site were considerably more fractured and broken than originally thought and rock quality was generally low. None of the borings intercepted the water table, and no observation wells were installed at the site.

Current Investigation

The current investigations included development of topographic base maps of the entire study area, and drilling exploratory holes and geologic mapping at the alternate dam alignment.

Topographic Base Map

The mapping work included surveying for a control network, placing temporary photographic panels, and completing aerial photography, scanning, photogrammetric mapping to produce a digital elevation model of the area. The digital elevational model was used to develop 2-foot contour topographic base maps of the Columbia River intake area, Black Rock reservoir site, Black Rock outlet area, and most areas in between. Existing USGS 7.5-minute quadrangle maps with 20-foot contour intervals provided topographic information for locations outside the coverage area, including a small portion of the outflow conveyance system between Black Rock Reservoir and Roza Canal and the Roza and Sunnyside delivery systems.

Exploratory Drilling and Geologic Mapping

Drilling, sampling, and testing were performed to determine the depth to bedrock and characterize the bedrock at the alternate Black Rock Damsite. Drilling was performed by Reclamation drill crews. Equipment included an Ingersoll-Rand A-220 truck-mounted rotary drill and a Gus Pech truck-mounted rotary drill, with standard support equipment including air compressors and circulating pumps. The top of bedrock confirmation holes (drill holes DH-03-1 through DH-03-5) were drilled using a 6-inch ODEX casing advancer system. Core samples of the bedrock were obtained, when possible, to verify the bedrock surface using HQ wire-line [2.5-inch inner diameter (I.D.)] coring systems with clear water as circulating fluid.

Two deep foundation borings were drilled. Drill Hole DH-04-1 was cored in order to define the deep foundation and DH-04-2 was cored to perform hydrogeology analysis. Both deep holes were drilled using an Ingersoll-Rand T-2 truck-mounted rotary drill with standard support equipment including air compressors and circulating pumps.

Coring was performed using a wire-line coring system with a polymer and water mixture used for circulating fluid. The upper part of the deep hole was advanced with PQ wire line (3.3-inch I.D.) and steel surface casing was later installed to stabilize the hole and enhance fluid return. The lower part of the hole was drilled using an HQ wire-line system with polymer and water as circulating fluid. Water for drilling was procured from a privately-owned water well located about 3 miles from the site.

The hydraulic conductivity test hole, DH-04-2, was drilled with standard rockbit and downhole hammers systems using a combination of air, water, and foam to remove the cuttings. Various water tests were conducted as the hole was drilled. Results are presented in the report entitled, *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

Borehole geophysical testing was conducted in six of the seven drill holes. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with geologic logs located in Appendix A.

Samples were tested in the field to determine magnetic polarity of the basaltic flows using a fluxgate magnetometer. The magnetic polarity was used to verify the general stratigraphic sequence of the basaltic formations encountered during drilling. In addition, core samples were submitted to the Washington State University GeoAnalytical Laboratory, Pullman, Washington, for geochemical analysis. Magnetic polarity results are shown on geologic logs and the geochemical analyses data and results are included in Appendix A. Dr. Robert D. Bentley, professor emeritus at Central Washington University, Ellensburg, Washington, provided valuable assistance in field tests and data analysis.

A report prepared under contract by Columbia Geotechnical Associates, Inc. gives an overview of the geology at the alternate damsite. The geologic mapping extended from the WIS Study to include the Black Rock Alternate Damsite. Results are presented in the February 2004 report (Lenz, Walls, and Bentley, 2004)

REGIONAL GEOLOGY

The Black Rock Dam and Reservoir sites are located in the northwest-central portion of the Columbia Basin, a structural and depositional basin that forms much of eastern Washington (Washington Infrastructure Services, Inc., 2003). The basin is the site of large basaltic flood lava known as the Columbia River Basalt Province. The basalts were erupted between 18 and 6 million years ago from vents near the present boundary between Washington, Oregon, and Idaho. Flows were up to 100 feet thick and covered hundreds to thousands of square miles. Extended time periods between eruptions allowed for the sediment deposition. Sediments consisted primarily of lacustrine silt and fluvial sand and gravel from the ancestral Columbia River and its tributaries. Basaltic eruptions over millions of years resulted in a stack of relatively horizontal flows that are referred to as the Columbia Plateau.

The western portion of the Columbia Plateau underwent north-south directed compression resulting in faulting and generally east-west trending folds. The folds are referred to as the Yakima Fold Belt. The ridges of the Yakima Fold Belt are generally asymmetrical, with one limb gently inclined while the other is steeply folded, often with a thrust fault near the base of the fold. Most of the structural relief, the Elephant Mountain Basalt of the Saddle Mountains Formation, has developed since 10.5 Ma, when the last massive outpouring of lava buried much of the central Columbia Basin (Reidel, Martin, and Petcovic, 2003). The anticlines represent the ridges and the synclines represent the valleys. This configuration exists at the Black Rock Damsites, which are sited between the Yakima Ridge anticline on the north and Horsethief Mountain/Rattlesnake Hills anticline on the south (refer to Figure 2).

Seismicity

A Preliminary Seismic Hazard Assessment was conducted by Reclamation to determine the seismic hazard at the Black Rock Damsite. Seismic loadings at the site are significant and for this study the thrust faults associated with individual folds within the Yakima Fold Belt have been considered as potential earthquake sources (Bureau of Reclamation, 2004c). Some potential exists for surface faulting associated with the Horsethief Mountain Thrust Fault in the right abutment and along the south edge of the reservoir (refer to Drawing 33-100-3381; all drawings are located in Appendix B).

Reclamation typically designs its power and pumping facilities for earthquakes having a return period of 2,500 years, and dams for earthquakes having return period of 10,000 years. For the damsite area, an earthquake having return period of 2,500 years has an estimated total Peak Horizontal Acceleration (PHA) of about 0.50g and at a return period of 10,000 years, the total PHA is about 0.95g (Bureau of Reclamation, 2004c).

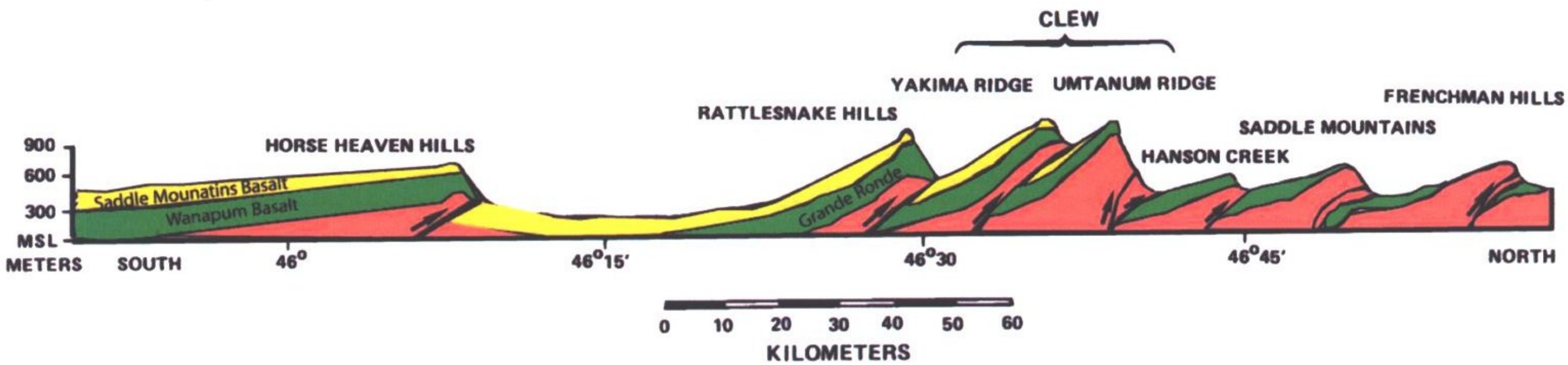


Figure 2. Generalized cross section through the Yakima Fold Belt (from Reidel and Campbell, 2003). The Black Rock Damsite is located between the Rattlesnake Hills and Yakima Ridge.

SITE GEOLOGY

Geologically, the foundation conditions at the two damsites are similar based on a comparison of material encountered in drill holes DH-1, DH-2, DH-3, DH-4, and DH-6 at the original site and drill holes DH-03-1 through -5 and DH-04-1 at the alternate site (refer to Drawing 33-100-3381). The sites are underlain by an interbedded sequence of volcanic and sedimentary rocks of the Columbia River Basalt Group and late Pliocene- to Holocene-age fluvial, lacustrine, and wind-blown deposits. The upper foundation is composed of Quaternary loessial and alluvial deposits underlain by sedimentary Tertiary Ringold Formation. The deep foundation bedrock is composed of volcanic rocks of the Saddle Mountain Basalt and upper Wanapum Formations of the Columbia River Basalt Group.

The geology and stratigraphy described here is based on exploratory drilling performed at the alternate Black Rock Damsite, and from interpretations of foundation geology presented in reports by Lenz, Walls, and Bentley (2004) and Washington Infrastructure Services, Inc. (2003). The alluvial units documented from drilling at the alternate Black Rock Damsite include wind-blown loess (Qe) and alluvial (Qh) deposits. These are underlain by the Tertiary Ringold Formation (Tr), which consists of fine- to coarse-grained sediments deposited within the Yakima Fold Belt. The underlying Columbia River Basalt Group consists of the Saddle Mountains Basalt Formation, which includes the Elephant Mountain Basalt Member (Tem), Pomona Basalt Member (Tp), and Esquatzel and Umatilla Basalt Members (Teq/Tum). The long periods between eruptions allowed for the deposition of sediments between flows. These sediments include sand and gravel bar deposits from the Columbia River, and finer-grained silt and clay layers deposited in shallow lake formed by temporary damming of the Columbia River. The sediments are known as the Ellensburg Formation and include the Rattlesnake Ridge Interbed (Trr), Selah Sedimentary Interbed (Ts), and the Mabton Sedimentary Interbed (Tm). At depth, the upper Priest Rapids Basalt Member (Tpr) of the Wanapum Basalt Formation was encountered. The main geologic units encountered at the alternate site are shown on the generalized stratigraphic section (refer to Figure 3) and are described in the flowing sections from youngest (recent) to oldest.

Quaternary Loessial Deposits (Qe)

Deposits of Holocene-age wind-blown loess blanket the site. The loess consists primarily of brown, dry to moist, fine sand, and nonplastic silt. The loess was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Quaternary Alluvial Deposits (Qh)

The alluvial deposits consist of undifferentiated coarse- to medium-grained sand with fines, gravel, cobbles, and boulders composed of basaltic detritus from local sources. The alluvium was encountered in test borings DH-03-1, DH-03-2, DH-03-3, DH-03-4, DH-03-5, and DH-04-1, and was differentiated from the underlying Ringold Formation at the alternate damsite based primarily on the coarse-grained nature of the unit (refer to Drawing No. 33-100-3383).

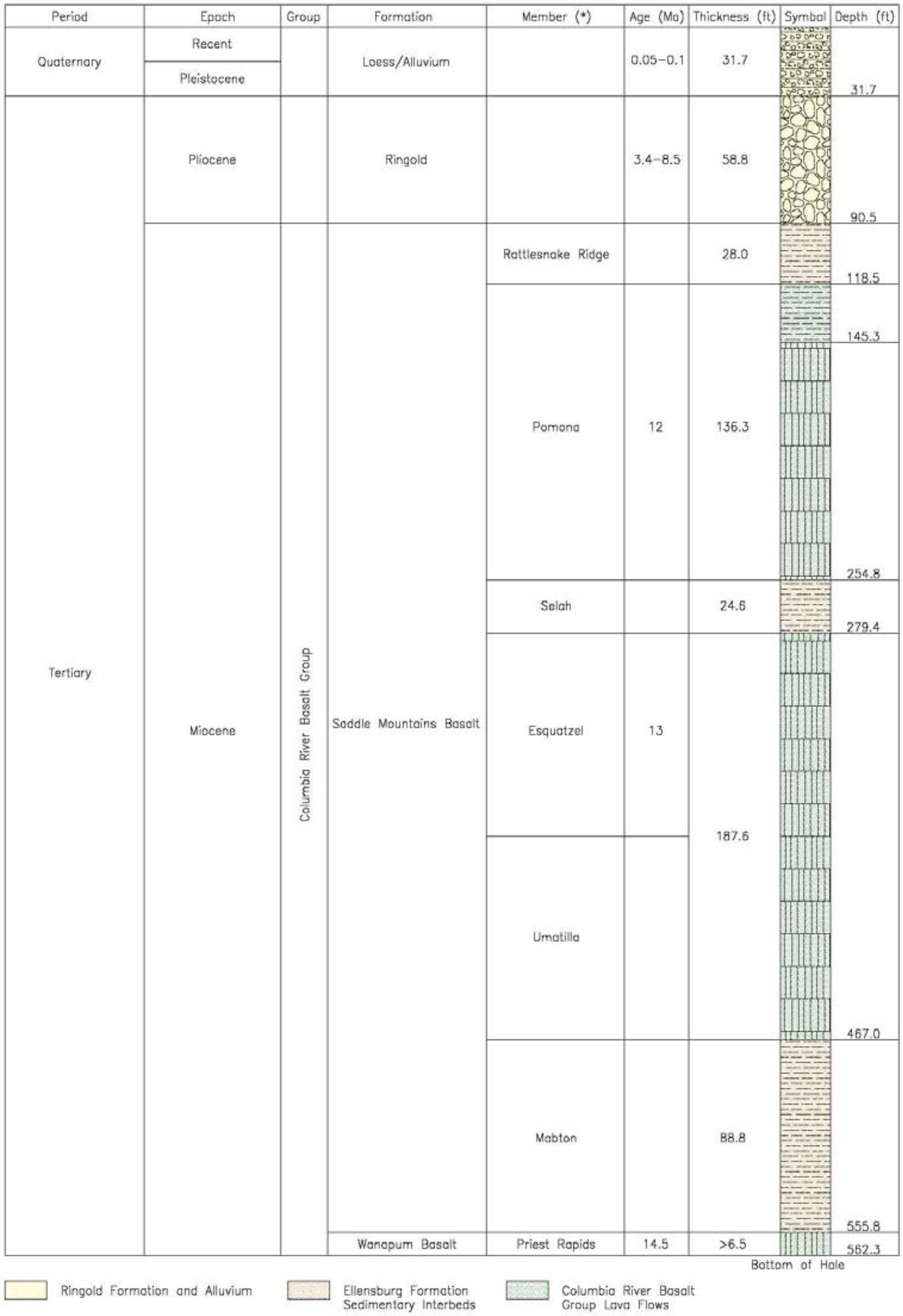


Figure 3. Generalized stratigraphic section of the alternate Black Rock Damsite based on drill hole DH-04-1 (adapted from Lenz, Wells, and Bentley, 2004; Washington Infrastructure Services, Inc., 2003; and Reidel and Campbell, 2003).

Ringold Formation (Tr)

The Ringold Formation is distinguished from the overlying alluvium based on a change from predominantly coarse-grained material to predominantly fine-grained material. The unit can be divided into three roughly equal sections. The upper and lower sections are coarser-grained fluvial deposits with material ranging from poorly- to well-indurated sand and fines, to gravel and fines with cobbles. The base of the Ringold Formation is characterized by a 10-foot-thick layer of cobbles. The middle of the formation is finer-grained, consisting of well-indurated clayey sand with gravel. The material is expected to be a firm foundation capable of supporting a large dam, although a seepage cutoff to bedrock may be necessary. The Ringold Formation was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Elephant Mountain Basalt (Tem)

The Elephant Mountain Basalt is the uppermost basaltic flow in the Saddle Mountains Basalt Formation. The Elephant Mountain Member was not encountered in the deep holes (DH-03-1 or DH-04-1) at the alternate damsite and may have been removed by erosion, but was encountered in a single hole (DH-2) at the original damsite (refer to Drawing No. 33-100-3382). The unit is a single, thin flow that consists of black, medium-grained basalt with small olivine phenocrysts (Washington Infrastructure Services, Inc., 2003).

Rattlesnake Ridge Interbed (Trr)

The Rattlesnake Ridge Interbed is a member of the Ellensburg Formation and includes the sedimentary deposits between the Ringold Formation and the Pomona Basalt Member. The unit is composed of fluvial gravel, sand, and cobbles with intensely weathered basaltic fragments and tuffaceous silt and clay. The unit represents sedimentary deposition of channel and floodplain materials in conjunction with eruption of Columbia River basalts. The Rattlesnake Ridge Interbed was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Pomona Basalt Basalt (Tp)

The Pomona Basalt underlies the Black Rock Valley and forms the foundation bedrock at the alternate damsite. The basalt has reverse magnetic polarity and contains fine plagioclase crystals as indicated in hand samples. The Pomona flow is invasive into the underlying Selah interbed and includes an upper thin contact zone of rafted sediments containing glassy vesicular basalt with inclusions of fine sediment. The altered sediments are referred to as a peperite due the textural characteristic of white tuffaceous sediments with scattered fragments of black basalt. The lower portion of the flow is slightly weathered, hard, intensely to moderately fractured basalt (refer to Photograph 2). The Pomona Basalt was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Photograph 2. View of Pomona Basalt core sample prior to removal from inner core barrel. The rock is slightly weathered, hard, and intensely to moderately fractured with tight to slightly open joints. The sample is from drill hole DH-04-1 from 191.4 to 210.4 feet. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.N. Stelma, February 24, 2004.

Selah Sedimentary Interbed (Ts)

The Selah Interbed is a member of the Ellensburg Formation and includes the sedimentary deposits between the Pomona and Esquatzel Members and Umatilla Basalt Member. The unit is composed mostly of tuffaceous siltstone and claystone consisting of reddish-orange to black, well-indurated clay to medium sand-sized lithic fragments of pumice, ash, and chert (refer to Photograph 3). The Selah Interbed represents deposition by the Columbia River and other streams between intense periods of volcanism. Additionally, the upper contact of the Pomona Member is interpreted to be an invasive flow, which is Selah Interbed sediments rafted to the flow surface during emplacement of the Pomona Basalt. The Selah Interbed was encountered in test boring DH-04-1 at the alternate damsite (refer to Drawing Nos. 33-100-3383 and -3384).

Undifferentiated Esquatzel and Umatilla Basalt (Teq/Tum)

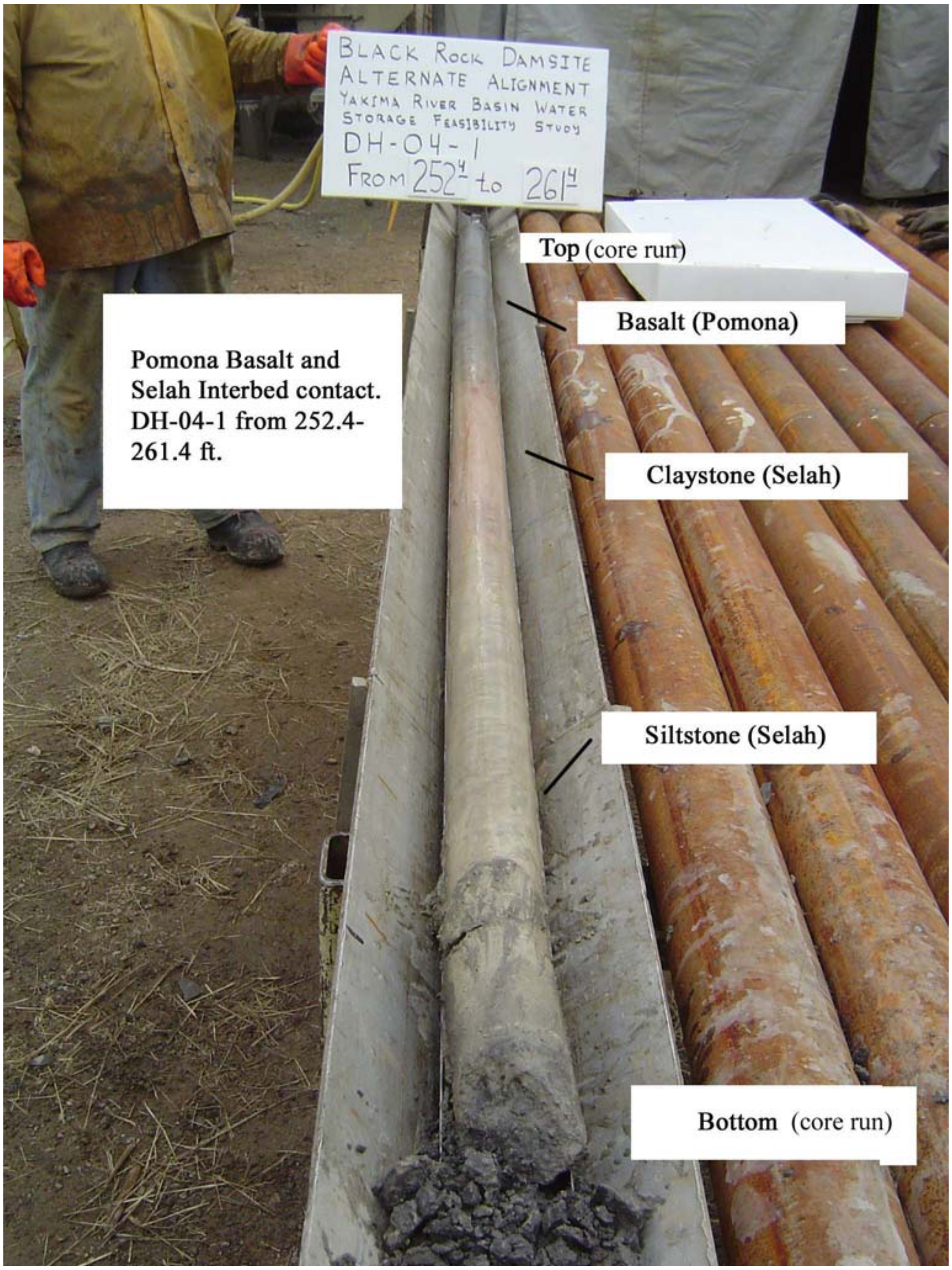
The Esquatzel Member is an intercanyon flow that filled ancestral Columbia River channels, sometimes overflowing the channel and pouring out into the floodplain (Washington Infrastructure Services, Inc., 2003). The Esquatzel Basalt overlies the Umatilla Basalt and it is impossible to visually distinguish between the two flows in hand samples. Both flows have normal magnetic polarity. Due to similar characteristics the members are addressed as a single unit on the geologic logs and in this report. The flows consist of gray to dark gray, hard, dense to slightly vesicular, fine-grained basalt that is slightly weathered. The units were encountered in test boring DH-04-1 at the alternate damsite (refer to Drawing Nos. 33-100-3383 and -3384).

Mabton Sedimentary Interbed (Tm)

The Mabton Sedimentary Interbed is member of the Ellensburg Formation and includes the sedimentary deposits between the Saddle Mountains and Wanapum Basalt Formations. The units consists of a thick sequence of tuffaceous siltstone, sandstone, and claystone that represents an extended time period of deposition between eruptions. The Mabton Interbed was encountered in test boring DH-04-1 (refer to Drawing Nos. 33-100-3383 and -3384).

Priest Rapids Basalt (Tpr)

The Priest Rapids Basalt is a member of the Wanapum Basalt Formation and is distinguished by stratigraphic position, and its coarse-grained texture and reverse magnetic polarity. It may be present near the top of the dam on the south abutment, near the hinge of a fold, and is expected to be fractured based on its location next to this structure (Washington Infrastructure Services, Inc., 2003). The Priest Rapids Basalt was encountered at depth in drill hole DH-04-1. Drilling was stopped after penetrating only 6.5 feet into the flow (refer to Drawing Nos. 33-100-3383 and -3384). Its total thickness at the site is unknown.



Photograph 3. View of core sample showing the contact between the Pomona Basalt (Saddle Mountains Basalt Formation) and the underlying Selah Interbed (Ellensburg Formation) prior to removal from coring tube. Note the reddish alteration zone at the contact. The sample is from drill hole DH-04-1 from 252.4 to 261.4 feet. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.N. Stelma, February 27, 2004.

ENGINEERING GEOLOGY

Two potential Black Rock Dam alignments were explored during previous and current geologic investigations. Geologic conditions at the original alignment are presented in the report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation* (Washington Infrastructure Services, Inc., 2003). The following sections discuss explorations conducted at the alternate alignment. The primary goal was to determine whether the bedrock surface was shallower at the alternate alignment than at the original alignment. Five holes were drilled to determine the elevation of the bedrock and a single deep core hole was drilled to obtain samples of the subsurface materials and provide a pilot sample hole for hydraulic conductivity testing. Ground-water conditions at the damsite are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b). The holes at the alternate damsite are located on the lower right abutment, in the channel section near the middle of the valley, and on the lower left abutment (refer to Drawing 33-100-3381).

The bedrock confirmation holes were drilled using a down-the-hole-hammer and compressed air. The contact was identified by sampling drill cuttings. Once the bedrock surface was reached, a short core run was taken to confirm and obtain a sample of the rock. The deep core drill hole was drilled using standard wire-line coring equipment. Drill holes DH-03-1 through DH-03-5 were abandoned in accordance with State of Washington requirements (backfilled with bentonite). A single slotted-pipe piezometer was installed in drill hole DH-04-1. For details refer to the geologic logs of drill holes DH-03-1 through DH-03-5, DH-04-01, and DH-04-2, all located in Appendix A. Also included in Appendix A is a tabular summary of samples for geochemical testing from drill holes DH-03-2, DH-03-3, DH-03-5, and DH-04-1. A tabulation of the results of the geochemical testing is also included.

Bedrock Surface Drill Holes

Due to the limitations of the drilling equipment, the bedrock surface was only encountered in three of the six holes drilled. However, based on the limited data, and a general understanding of the structural geology, the bedrock surface was defined sufficiently for engineers to estimate overburden volumes.

Drill Hole DH-03-1

Exploration drill hole DH-03-1 was located about 230 feet north of Washington State Highway 24, near the middle of the valley at the maximum section of the alternate dam alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 169.6 feet. Bedrock was encountered at about 146.9 feet (elevation 1201.8 feet). The upper 7.0 feet were loess (Qe), consisting of loose, dry, brown to tan, fine sand and nonplastic silt. From 7.0 to 30 feet the foundation was composed of alluvium (Qh). Samples were not obtained, but based on drilling and cuttings returned, the material was classified as coarse- to medium-grained sand with fines, gravel, cobbles, and occasional boulders. The Ringold Formation (Tr) underlies the alluvium. Based on drilling and cuttings returned, the material appeared to be mostly sand and fines, with some gravel and scattered cobble- and boulder-sized material. The Rattlesnake Ridge Member and the invasive Pomona flow top were sampled in DH-03-1, but based on information from companion hole DH-04-1, the units are likely present between approximately 90.0 and 146.9 feet. The bedrock encountered was part of the Pomona Basalt Member. Core samples taken consisted of black to gray, fine-grained, hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was intensely fractured (FD7) and samples recovered ranged from fragments to 0.4 feet in length, with most of the core around 0.33 feet. The fracture surfaces were mostly subhorizontal with smooth and planar surfaces. The rock quality designation (RQD) for the core run from 165.0 to 169.6 feet (bottom of hole) was 26 percent.

The drillers' attempted to install a four-inch diameter PVC pipe for borehole geophysical surveys. However, as the steel casing was being extruded it became lodged and broke off in the in the hole. The geophysical survey was unsuccessful in the steel-cased hole. The hole was abandoned by backfilling the steel casing with cement grout.

Drill Hole DH-03-2

Exploration drill hole DH-03-2 was located approximately 806 feet south of Washington State Highway 24, west of Horsethief Point, and north of dry Black Rock Creek near the base of Horsethief Mountain west of the alternate dam alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 73.9 feet. The upper 3.5 feet were loess (Qe) deposits, consisting of loose, dry, brown to tan, fine sand, and nonplastic silt. From 3.5 to 28.0 feet, the foundation was composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was classified as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned from 28.0 to 57.0 feet, the formation was fluivolacustrine in origin and was composed primarily of sand and gravel in a fine-grained matrix of silt and clay. The fines frequently plugged the compressed air portals at the drill bit and the down-hole casing hammer had to be retrieved several times to unplug the bit. A landslide block was encountered from 57.0 to 73.9 feet. Initially it was interpreted as bedrock, but subsequent information from drill holes DH-04-1, DH-03-4, and DH-03-5 showed that the rock encountered was probably too shallow to represent bedrock. The block rock appears to be composed of Pomona Basalt and likely represents a buried slide block that originated from the steep north limb of the Horsethief Mountain anticline, similar to Horsethief Point (refer to Geologic Section C-C', Drawing 33-100-3384). Core samples taken consisted of black to gray, fine-grained to slightly porphyritic (<5% phenocrysts), hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was intensely fractured (FD7) and samples recovered ranged from fragments to 0.4 feet in length, but most of the core was less than 0.33 feet in length. The fracture dip angles were mostly horizontal with some subhorizontal joints. The joint surfaces were mostly smooth and planar. The orientation of the block was not evident from the fracture orientations. The RQD from 66.3 to 69.8 feet was 0 percent and from 69.8 to 73.9 feet (bottom of hole), the RQD was 12 percent.

A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-3

Exploration drill hole DH-03-3 was located approximately 2,800 feet north of Washington State Highway 24, on the lower slope of the Yakima Ridge at the lower left abutment of the alternate dam centerline (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 99.0 feet. The upper 3.0 feet were loess (Qe) consisting of loose, dry, brown to tan, fine sand, and nonplastic silt. From 3.0 to 34.0 feet the foundation was composed of alluvium (Qh). Samples were not obtained, but based on drilling and cuttings returned the material was classified as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned, the formation from 34.0 to 87.0 feet was composed primarily of sand and gravel in a fine-grained matrix of silt. Geochemical test data indicate that the Elephant Mountain Basalt may be present based on a sample from 97.5 feet; refer to the summary of samples for geochemical testing in Appendix A. The geochemical test results were not conclusive. However, based on elevations and comparison with the other drill holes, the bedrock encountered is likely part of the Pomona Basalt. Core samples taken consisted of black to gray, fine-grained, hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was very intensely to intensely fractured (FD8). Samples recovered ranged from fragments to 0.2 feet in length, but most of the core was less than 0.1 feet in length. The fracture surfaces were mostly horizontal with rough and irregular surfaces. The RQD from 96.0 to 98.5 feet was 0 percent.

A four-inch diameter PVC pipe was installed for borehole geophysical surveys. A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content) and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-4

Exploration drill hole DH-03-4 was located approximately 350 feet south of Washington State Highway 24, near the middle of the valley at what would be the maximum section of the dam (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 105.5 feet. The upper 8.0 feet were loess (Qe) consisting of loose, dry, brown to tan, fine sand and nonplastic silt. From 8.0 to 50.0 feet, the foundation was composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was designated as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned, the formation from 50.0 to 105.5 feet (bottom of hole) was composed of sand and fines, with some gravel and scattered cobble- and boulder-sized material. The drill hole was terminated at 105.5 feet due to the limits of the drilling equipment.

A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-5

Exploration drill hole DH-03-5 was located approximately 900 feet south of Washington State Highway 24, west of Horsethief Point and within the dry Black Rock Creek channel at the base of Horsethief Mountain. Drill hole DH-03-5 was sited at the lowest point of the valley along the alternate alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 106.5 feet. The upper 32.5 feet were composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was designated as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drill cuttings returned, the formation from 32.5 to 106.5 feet (bottom of hole) was composed of sand and fines, with some gravel and scattered cobble and boulder-sized material. A possible slide block was encountered from 90.0 to 101.2 feet. The rock was shallow and may be a buried slide block that originated from the steep north limb of the Horsethief Mountain anticline, similar to Horsethief Point and the rock encountered in DH-03-2. The rock appeared to be Pomona Basalt. Core samples taken consisted of black to gray, fine-grained to slightly porphyritic (<5% phenocrysts), hard (H3), dense basalt. The core was moderately to slightly weathered (W4) with extensive oxidation of fracture surfaces extending into the body of the rock. The core was intensely fractured (FD7). Samples recovered ranged from fragments to 0.4 feet in length, but most of the core was less than 0.33 feet in length. The fracture dip angles were mostly 45 to 60 degrees from horizontal with smooth and planar surfaces. The RQD for the core run from 96.6 to 101.2 feet was 0 percent. Below the slide block the material was composed of poorly graded gravel with clay and sand (GP-GC). The drill hole was terminated at 106.5 feet due to the limits of the drilling equipment.

A four-inch diameter PVC pipe was installed for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Deep Foundation Drill Hole

The subsurface in the Black Rock Valley consists of surficial deposits of loess and alluvium, underlain by the Ringold, Saddle Mountain Basalt, and Wanapum Basalt Formations (refer Drawing Nos. 33-100-3383 and -3384). The Grande Ronde Basalt Formation also underlies the site at depth, but was not drilled or sampled during these investigations. Drilling at the original damsite was terminated at or shortly into the Pomona Basalt (refer to Drawing 33-100-3382). The maximum depth of drilling at the original site was 250 feet. Drilling for the deep hole (DH-04-1) at the alternate alignment was intended to be about 400 feet or approximately two-thirds the height of the potential dam, but was ultimately extended to over 560 feet in order to fully penetrate the Mabton Interbed. The deep hole also served as an observation well for down-hole water testing in a companion hole (DH-04-2). Results of the water testing in DH-04-2 and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

Drill Hole DH-04-1

Exploration drill hole DH-04-1 was drilled about 230 feet north of Washington State Highway 24, near the middle of the valley (refer to Drawing 33-100-3381). Continuous core samples were taken from the ground surface to the bottom of the hole at 562.3 feet.

The Black Rock Valley floor and slopes of the surrounding hills are mantled with wind-blown silt or loess (Qe). Loessial samples from DH-04-1 were composed of sandy silt s(ML). High-pressure air was used to advance the casing and core barrel in the loess. The resultant sample recovery was poor in the upper 5.0 feet and good from 5.0 to 7.0 feet. Samples contained about 70 percent nonplastic fines and about 30 percent fine sand, with some organic material in the upper few feet.

The alluvium (Qh) underlying the windblown silt was about 24.2 feet thick and was primarily coarse-grained gravel with medium- to coarse-grained sand and fines. Based on poor core recovery and drilling conditions, it was estimated that the alluvium also contained about 40 percent by volume cobble-sized (3- to 5-inch) material.

The Ringold Formation was distinguished from the overlying alluvium based on a change from predominantly coarse-grained to predominantly fine-grained material. The formation was about 58.8 feet thick and generally coarsened downward. From about 31.7 to 72.0 feet, the unit ranged from poorly graded sand with clay (SP-SC) to clayey sand with gravel (SC)g. From 72.0 to 80.0 feet, the material consisted of clayey sand with gravel and cobbles (SC)gc and the bottom from 80.0 to 90.5 feet was mostly cobbles with clayey sand (SC).

The uppermost unit of the Ellensburg Formation at the site is the Rattlesnake Ridge Interbed (Trr). The Rattlesnake Ridge Interbed was about 28.0 feet thick and the upper portion from 90.5 to 104.0 feet consisted of a weathered zone or palesol that may have developed prior to deposition of Ringold sediments. Below the weathered zone from 104.0 to 118.5 feet, the unit was composed of fine-grained, indurated silt- and sand-sized fragments of pumice and ash. This lower zone was derived from reworking of the underlying invasive flow debris that formed the upper surface of the Pomona Basalt Member (Tp).

The shallowest bedrock unit at the site is the Pomona (Tp) Basalt Member of the Saddle Mountains Basalt formation. The Pomona Member was about 136.3 feet thick and the upper section, from 118.5 to 132.0 feet, was composed of sediments rafted to the upper flow surface. The rafted debris, commonly referred to as an "invasive flow," was composed of peperite. The peperite was essentially reworked and rafted material derived from the underlying Selah Interbed (Ts), consisting of a mixture of mottled (greenish yellow to reddish brown), moist, clayey gravel with sand (GC)s, and silty gravel with sand (GM)s. The invasive flow top appeared highly permeable as indicated by substantial fluid losses once the unit was encountered during drilling.

The peperite that formed the upper portion of the flow and the basaltic bedrock were separated by a 12-foot-thick layer of poorly graded gravel (GP) composed of mostly fine, hard, subrounded to subangular clasts comprised of dense basalt, palagonitic basalt, and glassy basalt (obsidian). This layer represents a zone of heat alteration at the interface between the molten basaltic flow and the rafted sediments.

The body of the Pomona Basalt was primarily black to gray, slightly porphyritic, slightly weathered (W3), hard (H3), intensely fractured (FD7) basalt. The RQD from 145.3 to 254.8 feet (bottom of unit) ranged from 0 to 78 percent. For details of RQD refer to the log for drill hole DH-04-1 located in Appendix A.

The Selah Interbed (Ts) is a sedimentary unit underlying the Pomona basalt. The total thickness of the Selah Interbed was 25 feet. The unit consisted of massive, reddish orange to greenish yellow, intensely weathered (W7), soft (H3) to moderately hard (H4), intensely fractured (FD7) to slightly fractured (FD3) tuffaceous claystone, siltstone, and sandstone. The RQD from 254.8 to 277.1 feet (bottom of unit) ranged from 44 to 100 percent.

Because the Esquatzel and Umatilla Basalt Members (Teq/Tum) are difficult to distinguish and have similar physical characteristics, the two units are grouped together for discussion. The total thickness of the unit was 191 feet. The basalt was primarily black to gray, fine-grained, hard basalt. Overall, the RQD from 277.1 to 467.0 feet was generally good and fractured zones were generally limited to the upper and lower boundary of the unit.

The Mabton Interbed (Ts) is a sedimentary unit underlying the Esquatzel and Umatilla Basalt. The total thickness of the Mabton was 88.8 feet. The unit consisted of massive, mottled light green to greenish tan, intensely weathered (W7), moderately soft (H5), slightly fractured (FD3), tuffaceous claystone, siltstone, and sandstone. The RQD from 467.0 to 555.8 feet (bottom of unit) ranged from 0 to 100 percent.

The drill hole was terminated in the Priest Rapids Basalt Member (Tpr) at 562.3 feet. The polymer-based drilling fluid was rapidly lost once the hole penetrated the Mabton sedimentary layer. The body of the Priest Rapids Member was primarily black to gray, slightly porphyritic, slightly weathered (W3), hard (H3), intensely to moderately fractured (FD6) vesicular basalt. The RQD from 555.8 to 562.3 feet (bottom of unit) was 47 percent. Due to a total loss of drilling fluid, the hole was terminated at 562.3 feet. The fluid loss indicated that the upper portion of the formation was highly permeable.

A borehole geophysical survey was performed in the hole through the steel core drilling rods. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. After testing, the drill hole DH-04-1 was completed as a ground-water monitoring well (slotted-pipe piezometer) for ground-water testing in companion drill hole DH-04-2. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A.

Companion exploration drill hole DH-04-2 was drilled about 260 feet north of Washington State Highway 24, and about 30 feet north of drill DH-04-1 (refer to Drawing 33-100-3381). The hole was drilled for hydrologic testing. The results of the water testing and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b). Prior to water testing, a borehole geophysical survey was performed in the hole. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Upon completion of hydrologic testing the hole was completed as a ground-water monitoring well (slotted-pipe piezometer). Color plots of the borehole geophysical data and drill log are located in Appendix A.

Faults

The ridges of the Yakima Fold Belt are generally asymmetrical, with one limb gently inclined while the other is steeply folded, often with a thrust fault near the base of the fold. This configuration exists at the Black Rock Damsite, which is between the Yakima Ridge anticline on the north and Horsethief Mountain/Rattlesnake Hills anticline on the south (refer to Drawing Nos. 33-100-3381, -3382, and -3383). The depth and geometry of the Horsethief Mountain Thrust Fault are not known. Additional investigations are needed to define these traits as well as history of movement along the fault and potential for generating future earthquakes.

Washington Infrastructure Services, Inc.'s study of the original damsite suggested that a more suitable damsite may lie further west of the original study area (Washington Infrastructure Services, Inc., 2003). The location further west was believed to be less complicated, due primarily to the presence of a potential north-south fault, delineated by the "Macho Linear" thought to place the bedrock nearer the ground surface (refer to Drawing 33-100-3381). Reclamation performed investigations at the alternate site to confirm the depth to bedrock. Drilling results showed that the depth to bedrock and overburden thickness at the alternate site were slightly greater than at the original damsite, indicating that if a north-south fault exists between the sites, the offset is insignificant (refer to Drawing No. 33-100-3384).

Landslides

The extent and causes of potential landslides in the study area, and impacts due to construction activities and reservoir operations need to be established. The landslides in the Yakima Fold Belt generally form on sloping limbs of the anticlines, due to failure of the lower strength sedimentary interbeds. The primary areas where these conditions exist include Horsethief Mountain (south abutment) and potentially along the south rim of the reservoir area.

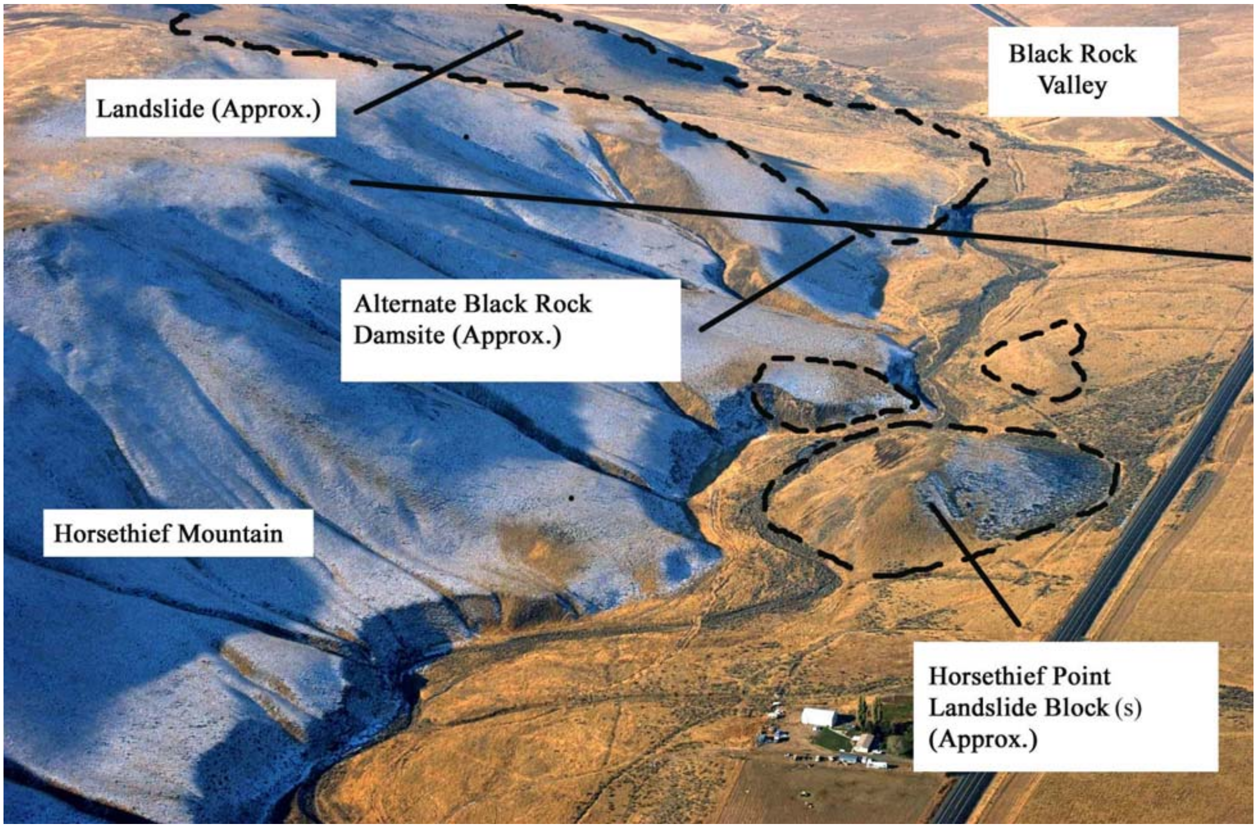
Several potential landslides have been identified on the Horsethief Mountain anticline (refer to Drawing 33-100-3381). One landslide is located on the north slope of the ridge upstream from the damsite (refer to Photograph 4). Horsethief Point is a prominent butte that projects from the valley floor upstream for the original damsite. This point appears to be a buried remnant of a landslide block that has moved off Horsethief Mountain (refer to Photograph 4). The third slide area is downstream from the damsite on the east slope of Horsethief Mountain (refer to Photograph 5).

Additional investigations are needed to evaluate the impacts of a potential reservoir on the landslide areas. In particular, potential landslides need to be identified and evaluated for impacts associated with the highway relocation along the south rim of the reservoir, the stability of slopes at the damsite during and after construction of the dam and appurtenant structures, and an evaluation of reservoir rim stability during reservoir operations.

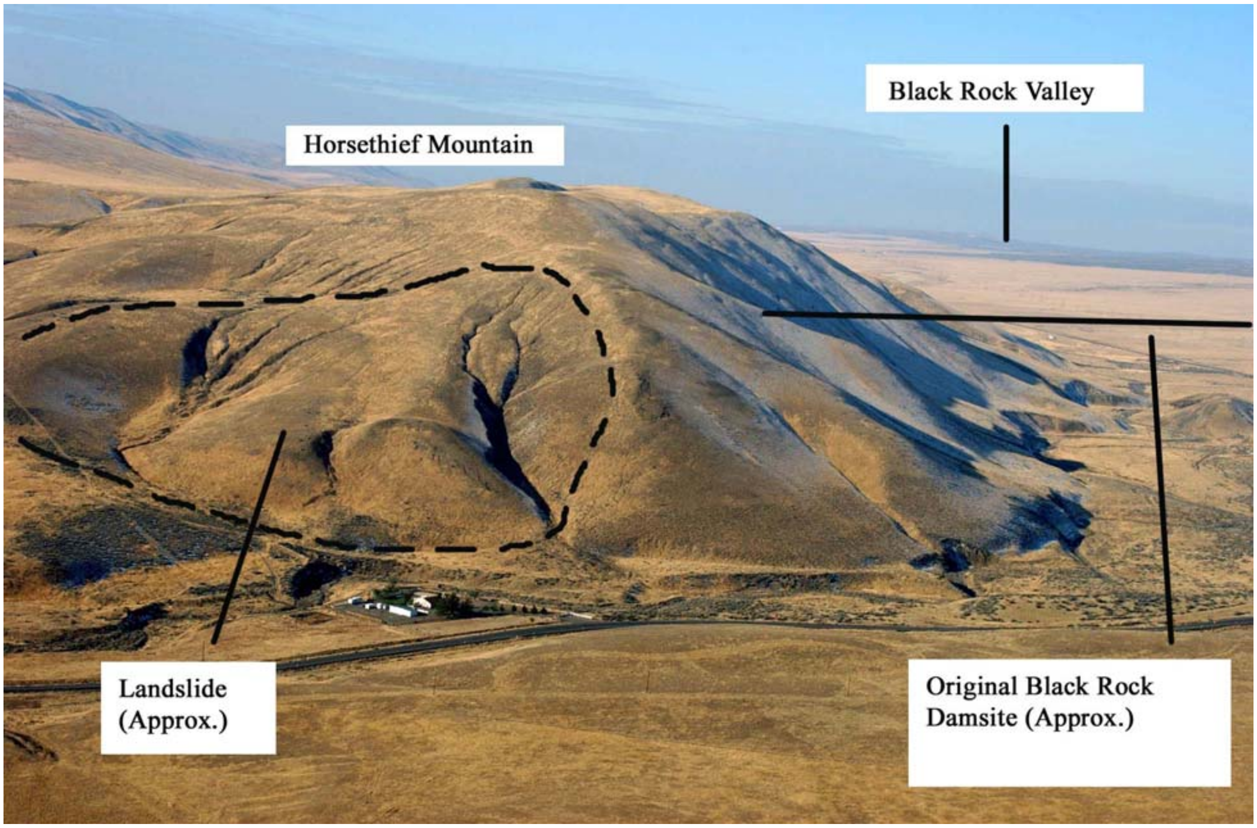
Comparison of Original and Alternate Damsites

As mentioned, Washington Infrastructure Services, Inc.'s report of the original damsite suggested that a more suitable damsite may lie further west of the original study area due to the presence of a potential north-south fault, referred to as the "Macho Linear" (refer to Drawing 33-100-3381) thought to place the bedrock nearer the ground surface (Washington Infrastructure Services, Inc., 2003).

Reclamation performed investigations at the alternate site between December 2003 and March 2004. These investigations involved drilling five shallow holes to define the bedrock surface and drilling one deep hole to confirm the stratigraphy of the deep foundation (refer to sections on *Bedrock Surface Drill Holes* and *Deep Foundation Drill Holes*). The exploratory drilling indicated that the depth to bedrock and overburden thickness at the alternate site was slightly greater than the original site. The depth to bedrock indicates that the potential offset along the postulated north-south fault, if the fault exists, is insignificant.



Photograph 4. View looking west at Horsethief Mountain, which forms the south (right) abutment at the Black Rock Damsite. Note landslide upstream of the alternate damsite on the northwest slope of the mountain. Horsethief Point and smaller rock outcrops to the west may be remnants of landslide debris derived from the north slope of the mountain. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.M. Walsh, November 6, 2003.



Photograph 5. View looking west at Horsethief Mountain, which forms the south (right) abutment at the Black Rock Damsite. Note the landslide downstream and south of the original damsite on the east slope of the mountain. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Photograph taken by D.M. Walsh, November 6, 2003.

Engineering estimates based on drill hole information show that for total embankment quantities, including above- and below-ground fill materials, the alternate site would require about 10,000,000 more cubic yards (yd^3) than the original site (Bureau of Reclamation, 2004a). Based on this data, the original damsite is the preferred alignment and no further study of the alternate damsite is planned.

The geology of the Black Rock Damsite was developed from the investigations conducted in December 2002 at the original site by Washington Infrastructure Services, Inc. (Washington Infrastructure Services, Inc., 2003). Both of the damsites are underlain by the same geologic units and the engineering properties of the shallow and deep foundation materials are similar at both damsites. Initial investigations indicate the site is adequate for construction of the dam. However, additional investigations are needed to confirm the amount of foundation excavation, the extent of foundation treatment needed, including grouting, and to evaluate potential landslides on the right abutment.

Recommendations for Future Investigations

If the Black Rock alternative proceeds to a feasibility-level study, recommended items for future investigations at the original damsite are as follows:

Maximum Section Area

Additional drilling will be needed to define the geometry of the Ringold Formation and top of bedrock with emphasis on a suitable intermediate foundation within the Ringold, and to define the extent and suitability of Elephant Mountain Basalt as a foundation, or determine if it will it be necessary to excavate down to the Pomona Basalt. Also additional water testing for permeability will help define criteria for grout curtain. Drill holes should be two-thirds the height of the dam or about 400 feet deep.

Abutment Areas

Additional drilling and water testing are needed to evaluate the permeability of the upper abutments. Water losses were highest in the upper abutment holes where little soil cover exists over the fractured rock. For details of water testing in the upper abutments at the original damsite, refer to the report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation* (Washington Infrastructure Services, Inc., 2003). The permeability information will also help evaluate seepage losses through the reservoir rim.

Horsethief Mountain Thrust Fault

The location and geometry of the thrust fault in the right abutment are not well known. Additional investigations are needed to define geometry, slip rates, movement history, and earthquake potential. The investigations likely will require both drilling and trenching.

GROUND WATER

The results of the water testing and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

BORROW MATERIALS

Nineteen potential construction material sources were identified on both developed and undeveloped sites within approximately 35 miles of the site. Descriptions of existing and potential borrow sites (mines) are summarized on Table 1 and approximate locations are shown on Figure 4. Following is a general summary of material types and approximate quantities required for the large reservoir central-core rockfilled dam. Quantities are based on informal engineering estimates. For details of the various material types, refer to Appraisal Assessment of *Black Rock Project Facilities and Cost Estimates, Final Report, Technical Series No. TS-YSS-2* (Bureau of Reclamation, 2004a).

Material Descriptions

Material Type	Description	Approximate Quantity (cubic yards)
Impervious Fill	Silt, clay, sand, and gravel	9,000,000
Rockfill	Gravel- to boulder-sized rock	81,750,000
Filter/drain materials	Processed sand and gravel	2,780,000
Concrete sand/gravel	Processed sand and gravel	185,000*
Cement	Cement	52,200* (tons)

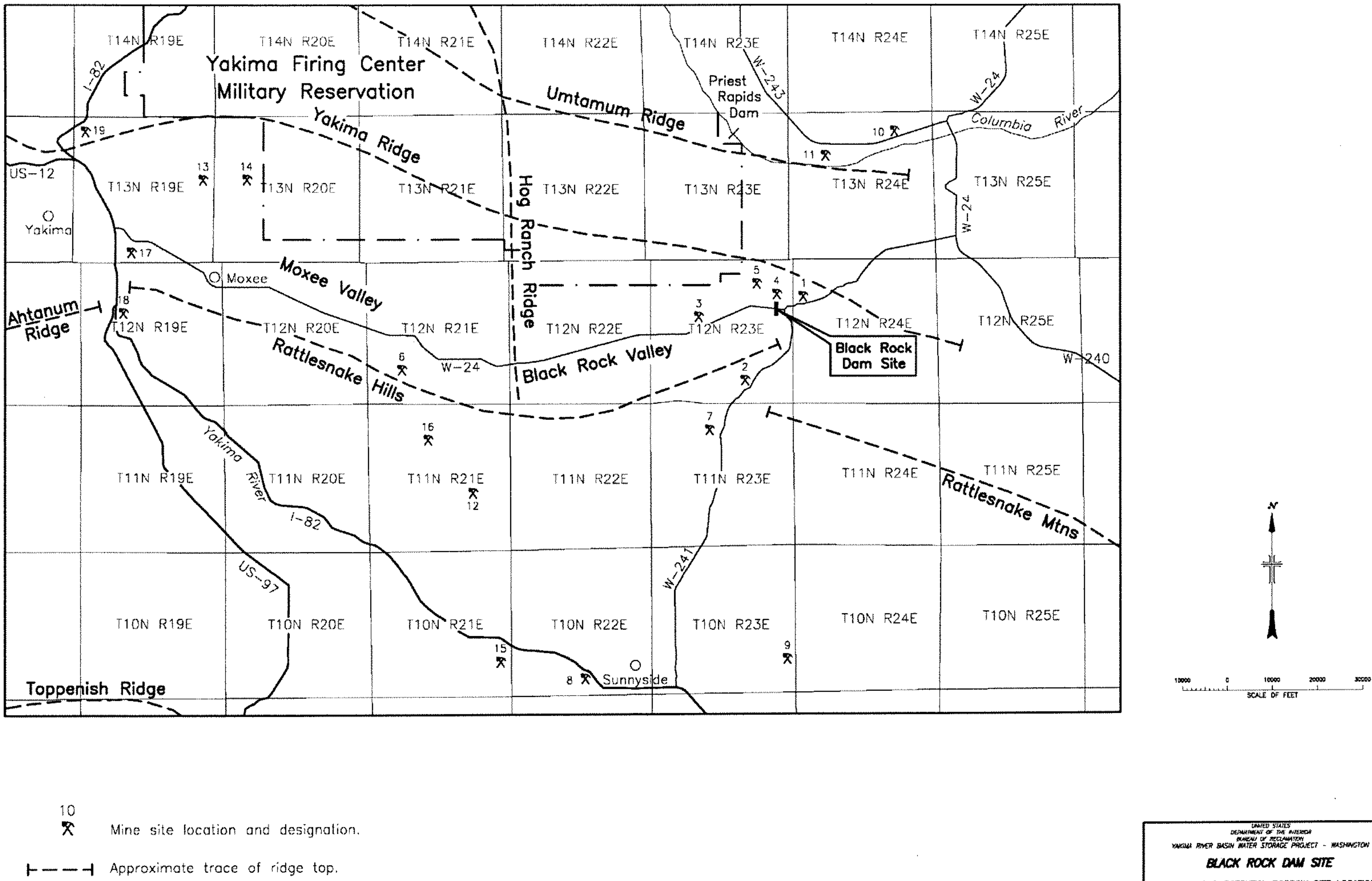
*Estimate for large reservoir concrete-faced rockfilled dam.

Black Rock Dam and associated structures can be constructed using materials mined locally from sources that consist of recent Yakima and Columbia River Alluvium, Post-Yakima Fold Belt Alluvium (including required excavation), and Columbia River Basalt (including required excavation). Impervious fill would have to be obtained by processing and separating fine-grained materials from Post-Yakima Fold Belt alluvial deposits located either in the Black Rock Valley or adjacent valleys. Borrow activities within the Black Rock Valley should be performed in a manner that would not alter the water-holding capability of the reservoir basin. Rockfill can be quarried from Columbia River Basalt and separated from required excavation. The nearest sources of material for processed sand and gravel are recent Columbia River alluvial deposits located east and northeast of the site. Yakima River deposits are located somewhat further away but can be utilized if necessary. Commercial sand and gravel mines are currently operating within both the Columbia and Yakima River floodplains.

TABLE 1

Summary of Existing and Potential Borrow Sites – Vicinity of the Black Rock Valley, Washington

Map No.	County	Owner/Permit Holder	Property Name	Section, Township, Range	Acreage	Depth (feet)	WDNR Permit Number	Commodity	App. Distance From Potential Dam Site (miles)
1	Benton	WDOT	OS-R-37	S. 7, T12N R24E	6.00	70	12813	Rockfill	2
2	Benton	Private	Dry Creek	S. 24, T12N, R23E	-	-	N/A	Impervious Fill	3
3	Yakima	WA State	Black Rock Valley (Black Rock Res.)	S. 16, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
4	Yakima	Private	Black Rock Valley (Black Rock Res.)	S. 21, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
5	Yakima	BLM	Yakima Ridge	S. 2, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
6	Yakima	BLM/Private	Rattlesnake Hills	S. 34, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	10
7	Yakima	Jeff Gamache Farms, Inc.	Black Starr	S.29, T12N R21E	15.00	25	12851	Rockfill	14
8	Yakima	Columbia Ready-Mix (Commercial)	Heffron	S. 34, T10N R22E	15.00	120	12907	Filter/Drain, Con. Aggregate & Sand	16
9	Yakima	WDOT	County Line	S. 25, T10N R23E	20.27	40	10631	Filter/Drain, Con. Aggregate & Sand	17
10	Grant	BOR	Columbia River	S. 3, T13N R24E	-	-	N/A	Filter/Drain, Con. Aggregate & Sand	18
11	Grant	Ellensburg Cement (Commercial)	Mattawa	S. 8, T13N R24E	36.00	40	12390	Filter/Drain, Con. Aggregate & Sand	20
12	Yakima	Yakima County	Liberty	S. 23, T11N R21E	16.27	50	10736	Filter/Drain, Con. Aggregate & Sand	23
13	Yakima	WDOT	Roza Hill	S. 13, T13N R19E	2.00	50	12202	Impervious Fill	24
14	Yakima	Cobra Const. Co. (Commercial)	Champoux Quarry	S. 17, T13N R20E	15.00	40	12000	Impervious Fill & Rockfill	24
15	Yakima	O.L. Luther Co., Inc. (Commercial)	O.L. Luther Pit	S.25, T10N R21E	80.00	40	12359	Filter/Drain, Con. Aggregate & Sand	24
16	Yakima	Superior (Commercial)	Zillah	S. 9, T11N R21E	100	-	13021	Filter/Drain, Con. Aggregate & Sand	25
17	Yakima	Central Pre-Mix Concrete (Commercial)	Riverside	S. 33, T13N R19E	40.00	40	11513	Filter/Drain, Con. Aggregate & Sand	25
18	Yakima	Columbia Ready Mix (Commercial)	Anderson Quarry	S. 17, T12N R19E	9.00	25	12801	Rockfill	26
19	Yakima	Superior (Commercial)	Rowley	S. 6, T13N R19E	62.01	200	12774	Impervious Fill & Rockfill	35



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE PROJECT - WASHINGTON

BLACK ROCK DAM SITE

EXISTING AND POTENTIAL BORROW SITE LOCATIONS

FIGURE 4

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